Tilapia Culture in the Senegal River Basin and the Causes of its Failure

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Abstract

Although tilapia culture in the Senegal river basin was promising at its beginnings, it now faces major difficulties (production < 50 tonnes). In spite of the many positive elements such as a vast water potential, abundance of by-products from agricultural and animal farming, and a deficit of about 21,000 t in fish supply from the river watershed, tilapia culture has not been successful. Its development has been affected by many constraints: (1) environmental—irregularity in the natural water system, poor mineral content in the rivers, high turbidity during the rainy season and low water temperatures from November to March; (2) technical—poor choice of sites, insufficient depth of the fishponds and inadequate dike construction, poor water quality control and poor fry quality; (3) administrative—poor definition of responsibilities, insufficient management support services and constant confusion in the experimental and extension objectives; and (4) socioeconomic—farmers' perception of fish farming as a secondary activity, high costs of construction and management, and competition with the fisheries sector. However, the construction of the Diama and Manantali dams seems to offer better prospects.

Introduction

After nearly 50 years of experiment, fish culture in many African countries has yet to realize its potential (Lazard et al. 1990). The production from fish farming for the African continent (62,000 $t \cdot year^{-1}$) and particularly, for subSaharan Africa (10,000 $t \cdot year^{-1}$) is low compared to the world production of 13 million $t \cdot year^{-1}$ (FAO 1989).

Although fish culture in Senegal gave early promising results, annual production does not exceed 100 t. The effort to develop tilapia culture in the Senegal river basin was encouraged by several factors. In the past two decades, the Senegal river basin had insufficient rainfalls and the land and water management strategies that were implemented drastically reduced flooded areas (Lazard 1981; Denneville and Jamet 1982; Diouf and Bousso 1988). From 400,000 ha in 1969, today these areas cover less than 100,000 ha (OMVS 1986). The reduction of flooded areas resulted in diminishing fish catches. From approximately 20,000 t in 1969 (Fall 1980), catches dropped to 8,000 t in 1988 (Diouf et al. 1991). However, the demand in fish continued to increase due to population growth. At present, the demand in fish for this region of Senegal is estimated at 21,000 $t \cdot year^{-1}$ (Diouf et al. 1991) considering the ideal consumption at 36.5 $kg \cdot head \cdot year^{-1}$ (Lazard 1981). Imports of marine fish from other regions of Senegal hardly make up a third of this deficit (Diouf et al. 1991).

Although the distribution channels for marine fish have become more efficient over the last few years, fish supply is still irregular in the landlocked areas such as the Bakel region (Fig. 1), especially during the rainy season, because of processing and transportation problems. In these regions, marine fish is expensive (Table 1) and often of poor quality (Diouf et al. 1991). In these areas, freshwater fish, particularly tilapia (from capture fisheries and fish farming) is preferred.

The average price of meat in the river basin is relatively high, especially in urban areas where it reaches approximately 800 F CFA·kg^{-1} (US$2.7). In rural areas, meat consumption is low because of social traditions. In this context, fish culture is needed.

Tilapia (essentially, *Oreochromis niloticus*) was chosen by developers because it is appreciated by consumers: it is a resistant species and farming techniques are relatively well-understood.

This article describes briefly the Senegal river basin environment, reviews its history of tilapia culture and assesses strengths and weaknesses.

The Environment

The Senegal river, approximately 1,800 km in length, is the seventh largest river in Africa and the second largest in West Africa. Its watershed covers an area of 340,000 km^2.

There are significant variations in the rainfall pattern across the basin: from 2,000 mm in the southern parts to approximately 300 mm at its northern limit.

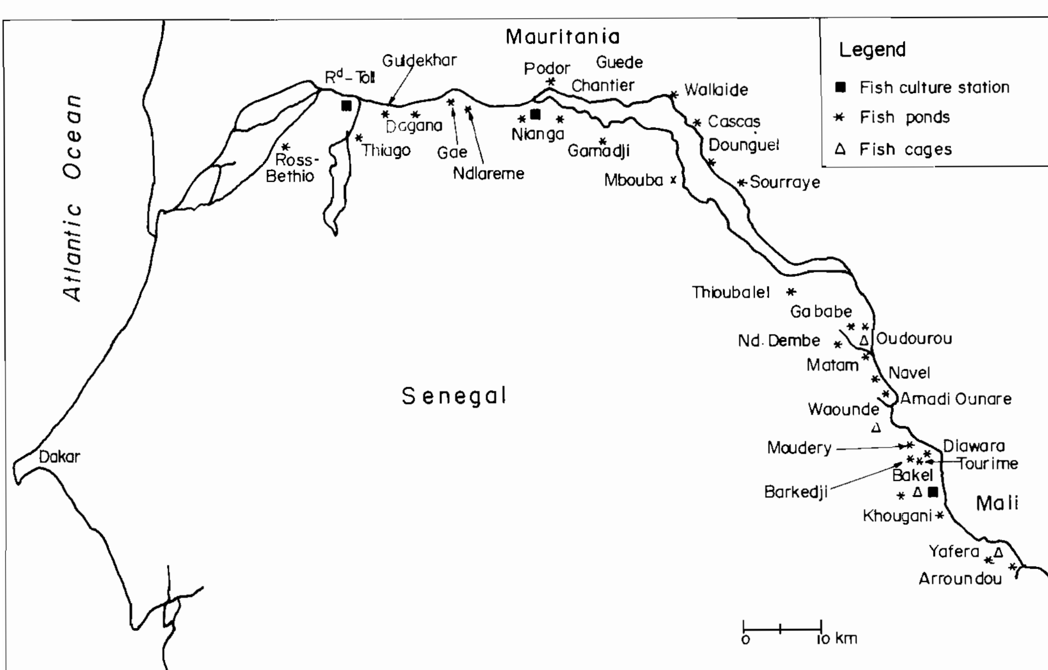

Fig. 1. Location of fish culture stations, ponds and fish cages along the Senegal River.

Table 1. Average retail price (F CFA)/kg of some marine fishes in Dakar (for comparison), Podor, Matam and Bakel between 1986 and 1987. (Source: Chaboud and Kébé 1990).

Species	Scientific names	Dakar	Podor	Matam	Bakel
Bonga	*Ethmalosa fimbriata*	96	138	227	400
Round sardinella	*Sardinella aurita*	107	176	232	295
Flat sardinella	*Sardinella maderensis*	77	188	231	296
Barracuda	*Sphyraena* spp.	426	600	481	589
Mullet	*Liza* spp. and *Mugil* spp.	280	383	425	540
White grouper	*Epinephelus aeneus*	554	711	752	603
Silver mullet	*Pomadasys jubelini* and *P. peroteti*	276	376	591	573
Cassava croaker	*Pseudotolithus senegalensis*	233	500	484	550
Meagre	*Argyrosomus regius*	435	699	689	576

US$1.00=300 F CFA at the time of the study.

In this region, annual rainfall patterns are highly irregular, particularly in the north.

The climatic history of this basin is characterized by a succession of dry and humid periods (Olivry 1982; Sow 1984; Kane 1985). At present, there is a persistent pattern of low rainfall.

Annual water evaporation is high. Data recorded with a Piche evaporometer over several decades showed mean values of 2,950 mm at Saint-Louis where the air moisture is relatively high, 3,220 mm at Matam and 3,550 mm at Rosso (Platon 1981).

The Senegal River system, classified as tropical by Frecault (1982), Gac and Kane (1985), and Kane (1985), is characterized by extreme year-to-year irregularity. The dams at Diama (Fig. 1) and at Manantali (Mali) will greatly modify this natural system. The objective of the Organization for the Development of the Senegal River (OMVS) is to substitute flood-recession farming by irrigated farming. However, to avoid drastic changes which would cause important socioeconomic problems, it was decided during the first years of operation that specific discharges (artificial flooding) would be allowed at Manantali to create and to maintain the necessary conditions for the pursuit of flood-recession cultures.

With regard to salinity, before the construction of the dams, freshwater covered the entire Senegal river basin in times of floods. But, from the second half of October, saltwater started to penetrate.

From the construction of the Diama dam, the tail-bay has operated as an evaporation basin and salinity has progressively increased up to 40-45 ppt. Upstream, freshwater is found as long as the dam remains closed.

The Senegal River water temperature shows seasonal variations due to two existing air temperature systems: a warm season (June-November) with water temperatures ranging from 30-33°C and a cool season (December-April) with temperatures ranging approximately from 16-26°C. Maxima of approximately

45°C and minima of approximately 12°C are recorded in ponds and shallow areas.

The valley and delta waters show different chemistry profiles. In the valley where there is freshwater all-year round, the water is tetraionic, poor in chloride, sulfate and minerals (Reizer 1974). The river productivity is low as a result. During floods, the delta waters show the same characteristics. In contrast, the seawaters in the delta during flood recession are hexaionic and rich in minerals. There is a progressive decrease in mineral content from downstream to upstream waters.

History of Tilapia Culture in the Senegal River Basin

Pond Culture (USAID and Catholic Relief Service)

PHASE I (1979-1981)

The history of tilapia culture started in the Senegal river basin with the signing in August 1979 of an agreement between USAID and the Senegalese Government for the funding of the "Intensive Fish Culture Accelerated Impact Project." The first phase of this project (December 1979 to December 1981), called "pilot" phase, involved major partners such as USAID, the Department of Forestry and Water Resources, the US Peace Corps and village-based cooperatives. In 1980, the Richard-Toll station was established with two 2,500-m^2 and four 500-m^2 ponds stocked with broodfish of *O. niloticus* from Côte d'Ivoire (FAO Project, Bouake) which in 1981 produced 50,000 fry to be used in demonstration ponds.

Also in 1980, 30,000-40,000-m^2 fishponds were constructed in the villages of Gaya, Ndiareme, Nianga, Guede, Gamadji and Mboumba (Fig. 1) stocked in October-November with fry from the Richard-Toll station at a density of 1.25-1.7 $fry \cdot m^{-2}$.

In March 1981, the project was evaluated before the ponds were harvested for the first time. According to the conclusions of this evaluation, the project was working well and chances of success were high.

After four-and-a-half months, the fish weighed between 90 and 125 g. Results of the first year of experiment were encouraging with mean yields of 1.2 $t \cdot ha^{-1}$ (Freudenberger 1988).

As reports on this period are not available, it is impossible to reconstruct the details concerning the management of these ponds. However, our inquiries show that feeding and fertilization were essentially based on rice bran and organic fertilizers.

PHASE II (1982-1984)

At the end of the first phase, the USAID funded a second two-year phase under the Bakel Irrigated Areas Project. During this period, the participation of the Senegalese Government was entrusted to the Société pour l'aménagement et l'exploitation des terres du Delta (SAED).

During this period, two new fish farming stations were constructed: Bakel (1982-1983) and Nianga (1983-1984). Forty additional demonstration ponds were constructed, but most of them had to be abandoned because of their disappointing results.

To reduce competition with marine fish, fish culture initiatives were moved to the eastern and central areas of the Senegal river basin.

The Bakel station possessed two 3,500-m^2 and one 7,500-m^2 ponds. It produced only 15,000 fry for the ponds of Arroundou, Koungani, Yafera and Wallalde (Fig. 1).

The Bakel station experienced serious difficulties due to water infiltration and management problems. The ponds were managed by a fisheries cooperative with the assistance of a volunteer worker from the US Peace Corps. Some members of the group, relying on their own experience in fisheries and "knowledge of fish," refused to follow the recommendations of the volunteer worker. Following poor harvests in 1984, the Bakel station was abandoned.

During this second period, the quality of the fry produced at the Richard-Toll station decreased due to the high stocking densities of the broodfish.

Paradoxically, the number of demonstration ponds increased dramatically in the villages while harvests remained less than adequate.

Although information on feeding during this period is insufficient, Lazard (1984) indicated that a mix containing 90% rice bran and 10% fish meal was used at the Richard-Toll station.

PHASE III (1985-1988)

The ponds of the Nianga station were stocked at the end of 1984 and beginning 1985 with *O. niloticus* coming from Richard-Toll, Lake Guiers, the canals around Podor and the Guidekhar pond.

The station produced 20,000 fry during the first year of operation. One of the breeding ponds was stocked during the first season with *Sarotherodon galilaeus*. No data are available on the results of this operation.

During Phase III, the station supplied fry to the neighboring ponds and cages, although insufficiently.

At Nianga, as in the village demonstration ponds, the feed contained 80% rice bran and 20% fish meal. Other mixes were used (blood meal, peanut cake, etc.) without much success.

Experiments conducted at Nianga showed that a density of 2 fry$\cdot$m^{-2} gave better yields than 1 fry$\cdot$m^{-2}. Yields obtained with the former density were 1.66 times higher than with the latter (2.427 t$\cdot$ha$^{-1}\cdot$year^{-1} against 1.462 t$\cdot$ha$^{-1}\cdot$year^{-1}). In contrast, the density of 2 fry$\cdot$m^{-2} was 1.4 times less profitable because of the added feeding and fertilizer loads (Freudenberger 1988).

Moreover, small ponds (2,750 m^2) were more productive (1.462 t$\cdot$ha$^{-1}\cdot$year^{-1}) than large (33,000 m^2) ponds (0.850 t$\cdot$ha$^{-1}\cdot$year^{-1}).

In 1985, four years after the beginning of the project, a second evaluation revealed that results were much poorer than expected.

In March 1985, the USAID stopped funding the project. This period coincided with vast social and management problems. Funding by the Catholic Relief Services (CRS) resumed in March 1985.

Based on a new evaluation (Freudenberger 1988), CRS also decided to stop funding the project. The conclusions of the evaluation were as follows:

> "The fish farming project has largely missed its primary objective which was to show concrete proof of its feasibility in the form of successful demonstration ponds, and to show such proof to the different farmers by creating an efficient demonstration program. Neither did this project reach its objectives to help the local farmers increase the quantity and the availability of proteins in their diet, nor did it succeed in increasing their individual income."

Cage Culture

Due to the difficulties encountered in facing the costs of water and pond construction, cage culture experiments were started in 1984 in Bakel and Waounde. Cages were constructed using PVC pipes and wire netting coated with a rust-proof plastic material. Because of strong currents, the cages did not last for more than a month. Research studies were done to find a solution to this problem and new techniques were tested in June 1985, leading to the creation of new cages made of nylon nets and iron bars.

The fish feed was essentially composed of a mix of 80% rice bran and 20% fish meal. Results were not encouraging.

Extensive Fish Culture

Trials in extensive fish farming were started in the Guia flood plain near the Nianga station. On 2 October 1986, the area was stocked with 2,000 fry of *O. niloticus*. The fish were exclusively fed with rice bran. At the end of June 1987, 895 fish or 24.6 kg were harvested, which discouraged farmers.

Rice-fish Culture

Attempts to develop rice-fish culture were made by volunteers of the US Peace Corps at Ndiareme (Dagana). The project was funded by the USAID and was supported by various public and private organizations such as SAED, the West Africa Rice Development Association (WARDA), the Senegalese Institute for Agricultural Research (ISRA), the Department of Forestry and Water Resources, the Senegalese Sugar Company (CSS), FAO, the US Peace Corps and USAID.

The project used *O. niloticus* and a cold-tolerant, usually high-yielding rice variety (KN-1H-350) from Indonesia.

According to Chopak (1983) and Bloom (1986), all objectives were achieved. Unfortunately, after two seasons of experiment (1982-1983), the USAID stopped funding the project despite encouraging results (Tables 2 and 3).

The Matam III Project

Under the Water and Agriculture Development Project of the district of Matam, Phase III, an aquaculture project was developed. This project, Matam III, started in September 1986 and was funded by the Caisse centrale de coopération économique, and developed by SAED and the Association française des volontaires du progrès (AFVP). The Department of Forestry and Water Resources was responsible for the execution and the administrative support of the project. Four fish farms were created. Construction works were of poor quality: pond depth was insufficient, dikes were prone to erosion and monk drains were poorly built.

In October 1990, only two complete production cycles of marketable fish had been achieved and two other cycles were ongoing. The evaluation of October 1990 (Parrel 1990) revealed that:

- out of the 10 fish farms previously expected, only four were constructed due to the difficulties in finding available and competent firms to undertake such constructions;
- none of the farms was fully operational and infrastructures were of relatively poor quality;
- the support services encountered real difficulties in efficiently mobilizing the fish farmers whose training was insufficient;
- yields were disappointing; and

Table 2. Comparative yields from rice culture, fish culture and rice-fish culture in Senegal. Source: Chopak (1983).

Type of culture	Yield ($t \cdot ha^{-1}$) Fish	Rice
Rice culture	-	4.800
Fish culture	2.134	-
Rice-fish culture	2.098	4.500

Table 3. Costs and returns (for a one-hectare pond, ricefield and rice-fish culture field). All costs are in CFA francs. US$1.00=300 F CFA at the time of the study. Source: Chopak (1983).

Item	Rice culture	Fish culture	Rice-fish culture
I. Equipment			
- Machine rental and labor	90,000	188,000	218,800
- Material	20,000	58,200	49,200
Total	110,000	246,200	268,000
II. Operational costs (per season)			
- Water	25,000	30,000	40,000
- Fry	-	20,000	20,000
- Fertilizer	37,700	87,000	107,200
- Feed (rice bran)	-	60,000	60,000
- Rice seed	9,900	-	9,900
- Machinery	70,306	-	70,306
- Marketing	5,000	7,500	15,000
- Labor	160,000	162,000	190,000
- Rental	-	-	-
Total	307,906	366,500	512,406
III. Returns			
- Fish sales (150 CFA·kg^{-1})	-	320,100	314,700
- Rice sales (66.6 CFA·kg^{-1})	319,680	-	299,700
Total	319,680	320,100	614,400

– the project team lacked "professionalism."

According to Parrel (1990):

> "The current failure of this project is therefore not that of fish culture, inasmuch as aquaculture is successfully developed in Niger (Lazard et al. 1990) in similar climate and physical conditions, and that the production techniques of *O. niloticus* are now well-understood for this type of culture. This failure is therefore more the failure of a particular operation and to accept failure, after that of the Peace Corps project, means to condemn the development of fish farming in Matam for many years."

In an attempt to give the development of fish farming another chance, Parrel (1990) proposed an extension of the Matam III fish culture project until 31 December 1992 provided that a new approach was taken with necessary changes.

Strengths and Weaknesses of Tilapia Culture in the Senegal River Basin

Strengths

The Senegal river basin holds a considerable water potential. In addition to the 1,800 km-long main watercourse, the river basin includes lakes, the most important of which, from the viewpoint of Senegalese aquaculture, are the Lake

Guiers and the hill lakes. In addition to these water bodies, there are many ponds (DEFC 1988). Moreover, agriculture and animal farming are highly developed in this region and the by-products necessary to fish farming are therefore available. However, the competition for food between cattle and farmed fish may occasionally create some problems. In the Senegal river basin, the shortage in fish is great and there is therefore a potential market for cultured fish.

The construction of the Diama and Manantali dams constitutes a positive factor for tilapia culture for several reasons:

– water supply becomes regular and cheap;

– agriculture development is possible and consequently by-products used for tilapia culture increase; and

– the likely increase in revenues for the farmers should improve their purchasing power.

Finally, one of the major strengths of fish culture is the will of the State to develop this sector of activity.

Weaknesses

ENVIRONMENTAL CONSTRAINTS

The great irregularity of the natural water system in the Senegal River constitutes a disadvantage for tilapia culture. High variations hinder efficient water management and threaten fish farming in certain areas.

In addition to this constraint, high evaporation in the major part of the watershed and permeable soils in some areas (Bakel) require the regular recreation of pond water levels.

Moreover, the low level of minerals in the waters of the Senegal River (Reizer 1974; Diouf et al. 1991) constitutes a negative factor for tilapia culture. To improve growth, fish farmers are constrained to put additional nutrients in the ponds. These extra expenses increase the already high costs of production.

During the rainy season, the waters of the Senegal River are generally muddy, increasing turbidity in the ponds. In turn, water turbidity greatly affects the production of phytoplankton, reducing the trophic resources of the ponds. This phenomenon is particularly pronounced in Matam.

From November to March, water temperatures are relatively low (down to 16°C), resulting in a decreased or stunted growth in the pond fish.

The flat lowland terrain often causes problems in the construction of ponds and additional costs for filling and drainage.

ADMINISTRATIVE AND TECHNICAL CONSTRAINTS

The history of the Senegalese fish culture reveals that the choice of sites (Bakel and Navel, for example) has not always been wise. The location of the ponds is extremely important for the technical and economic success of fish farming.

Ponds are not always constructed according to the technical standards required for sound management (lack of depth and poorly constructed dikes).

In addition, the large size of the ponds is often responsible for poor water management.

Defective pond construction is related, on the one hand, to the lack of heavy machinery and to the lack of experienced fishpond technicians, on the other hand.

A major obstacle to the development of fish farming has been the near constant confusion between the objectives of research and extension. Very often, fish culture techniques have been extended before being fully mastered. This has resulted in failures that have strongly shaken the enthusiasm of farmers, even though efforts in this direction are evident at the stations of Ndouloumadji Dembe and Nianga.

With regard to water quality, the lack of routine control of physico-chemical parameters is to be deplored, even though efforts in this direction are evident at the stations of Ndouloumadji, Dembe and Nianga.

The availability of fry, both in qualitative and quantitative terms, has often been a major constraint. Freudenberger (1988) says of the Richard-Toll station:

> "It is difficult to remember a single moment where fry produced at Richard-Toll fully satisfied the needs of the village fishponds. During the first year of operation, the fishes provided were larger than fry, and during the following years, problems occurred in the breeding ponds which resulted in overstocking and stunting. In fact, the largest part of the fish provided to the village ponds during this period may have been stunted animals rather than real fry. When they were introduced in the ponds, they bred immediately becoming once more too many for the ponds, greatly reducing the yields."

The insufficient and inexperienced management staff (Shelton 1985; Freudenberger 1988) played an important role in the failure of fish farming. This was aggravated by a lack of coordination and poor relationships among the various organizations involved in fish culture in the Senegal river basin.

Also, poor project management and administration seem to have contributed to the failure of fish farming in the Senegal river basin. At least, this is what transpired from the interviews conducted with a number of persons involved in fish culture.

SOCIOECONOMIC CONSTRAINTS

One of the major obstacles to the profitability of fish farming in the Senegal river basin is undoubtedly the high costs of construction. For example, construction costs (main works) for one hectare have been estimated at approximately 8 million F CFA or US$26,700 (Corlay and Seck 1988), which farmers cannot afford.

At this point, it is legitimate to wonder whether fish culture in the Senegal river basin should or should not be subsidized.

The principle of funding aquaculture is widely accepted, particularly in France where up to 50% of total investments can be subsidized (Corlay 1989). It should be pointed out that in Senegal, rice culture, a financially deficient activity, is subsidized for nearly half its price to consumers [against 160 F CFA/kg (US$0.50); 70 F CFA (US$0.20) is subsidized]. Similarly, in the fisheries sector, fuel and fishing gears are subsidized. However, under the Senegalese current economic policy, subsidies to fish farming are difficult to imagine.

With the improvement of distribution channels, marine fish compete seriously for markets with cultured fish (Chaboud and Kébé 1990). In particular, the increase in the number of refrigerated trucks for the transportation of fisheries products has considerably increased the fishmongers' scope of activity.

Fish farming also competes with other activities such as agriculture, animal farming and capture fisheries which are traditional activities that are well integrated into the social life of the people, and take precedence over fish culture. This explains certain attitudes towards fish farming. For example, a number of these farmers are skeptical about investing their physical or financial resources in fish farming activities, thinking that these resources would be more profitable if invested elsewhere (agriculture, animal farming or capture fisheries), particularly when fish farming has yet to prove successful.

Moreover, cooperatives have been an obstacle to the development of fish culture. Ponds run by a cooperative generally face enormous management problems which threaten the success of this activity and local politics often aggravates the situation.

Discussion

After a little over 10 years of efforts in developing tilapia culture in the Senegal river basin, successes are extremely rare, even nonexistent. We should therefore admit that tilapia culture has failed in this region.

This failure is related to several environmental, technical, administrative and socioeconomic factors which should be analyzed.

Concerning environmental factors, the extreme irregularity in the Senegal river basin water system has long been a major constraint. However, the Diama and Manantali dams can solve this problem. In contrast, the problems of high evaporation, unsuitable terrain, poor water mineralization and turbidity are not likely to be economically soluble.

The choice of sites for fishponds has not always been sensible, particularly in Bakel and some areas of Matam III. A brief study of soils and a summary analysis of the socioeconomic environment would have prevented errors that have greatly contributed to the failure of fish farming in the Senegal river basin.

Defective pond construction has also acted against fish culture. The solution to this problem involves the improved training of pond workers and the hiring of consultants knowledgeable about African and tropical aquaculture. The choice of consultants requires particular attention. Some consultants have set high professional standards and given excellent results, but there are also agencies and independent consultants whose competence and even integrity are questioned.

The absence of routine control of the physicochemical parameters and of a collection of economic and financial data on fish culture, although two distinct problems, greatly affect the success of fish farming operations. It is clear that under such conditions, the chances of success of fish culture are limited.

Regarding administrative factors, fish farming has suffered from its own management system. It is time for the financial and technical management of fish culture projects to be decentralized. Funds should be allocated to project directors. This decentralization will have to be accompanied with regular technical, administrative and financial evaluations. Stringent management practices will also be required from project directors.

All these constraints bring forth the basic issue of the relevance of new perspectives and efforts in fish farming.

In the Senegal river basin, the production from inland fisheries has strongly declined and no longer satisfies the protein requirements of the local populations (Diouf et al. 1991). A solution to this problem would be to improve the distribution channels of marine fish by reinforcing the road infrastructure and the processing and storage facilities for fisheries products. However, this solution may not be achievable in time. For example, the Senegalese population is continuously growing, and although resources are currently well-managed, they will not be able to respond to a considerable increase in population and may collapse as a result

(Bakhayokho et al. 1985). It is therefore to be expected that in some years, marine fisheries will no longer be able to satisfy the demand in fish. The price of marine fish is likely to increase, thereby increasing the competitiveness of cultured fish on the markets of the Senegal river basin.

The price of meat, which could replace fish, is relatively high and out of reach for most rural people.

This new scenario seems to encourage the development of fish culture, which should be further improved by a sufficient and regular supply of water from the dams.

It would be therefore sensible to prepare the grounds for such development by establishing experimental and research structures that will help develop efficient fish farming methods. This period, likely to last five to 10 years, will determine the future success of fish farming.

This approach will prevent the basic error that has been committed from the beginning of fish culture development in the Senegal river basin, namely, to give production precedence over research. This attitude was dictated by the conviction of fish culture developers that techniques developed in other countries could be directly transferred to Senegal. Experience has shown that the local dimension of fish farming is very important: farming techniques must be adapted to each environment.

The choice of the type of fish culture to be developed in the Senegal river basin is crucial for determining the success of future developments. Subsistence aquaculture is unlikely to succeed. The level of technicality required to develop fish farming makes subsistence aquaculture economically unattractive (Lazard et al. 1990). This explains why farmers rapidly lose interest in this kind of operation.

Concerning industrial fish culture, the experiment showed that most operations of this type have failed, the production costs remaining substantially higher than market prices (Lazard et al. 1990).

The type of fish farming that presents the best chances of success is certainly artisanal fish farming: small-scale commercial production, integrated with existing agricultural farming systems. This type of operation presents the advantage of providing farmers with additional income while not requiring large investments.

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